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Heat Transfer Enhancement during Flow Boiling of Refrigerant in Horizontal Copper tube Using Twisted Tapes

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Abstract: Heat transfer enhancement in the heat exchangers like evaporators, condensers and many more are considered as a stringent research issue in today's energy crisis and associated economic, social and environmental concerns. In most of industrial heat exchangers, flow boiling or evaporation is the major phenomenon for different applications. Using R-407C as a refrigerant and Twisted tapes as passive techniques in modified evaporator section heat transfer enhancement is achieved. The heat flux values are varied here from 2-20 kW/m^2 and two distinct flow rates as 95 and 112 kg/m^{3}s are taken to get the experimentation. This system gives efficient heat transfer enhancement values as well as lowering the chances of harming environment due to use of R-407C.
Keywords: Flow Boiling, R-407C, Horizontal tube, Heat transfer, Refrigeration

I. INTRODUCTION

Extravagant use of energy by a human kind for his modern and luxurious life is creating energy crises, social issue as well environmental. Savings in conventional energy is now a big issue on research platform. Most of the conventional form of energy is consumed in converting to useful form of work, boilers, re-boilers etc. are the key components in heat exchange process to produce the desired effect, such as mechanical power, cooling or heating effect in refrigeration and air conditioning system. So, if heat transfer enhancement takes place effectively here, it will increase the performance of these heat exchangers and in turns will increase the efficiency of work producing system or heat actuated System.

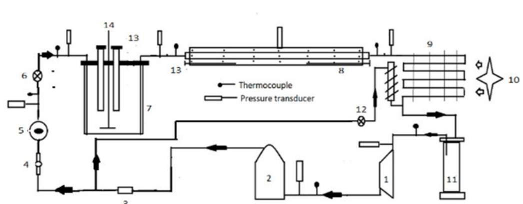
Twisted tapes are one of the passive techniques which includes surface geometries for heat transfer enhancement. It enhances the proper mixing of fluid and also avoids formation of laminar sub-layer which gives enhanced rate of heat transfer [1]. Also using R-407C as a refrigerant helps in avoiding usage of R-22 which has higher GWP values as it shows comparatively less value of GWP and zero value od ODP. [2]-[4].

II. EXPERIEMENTAL SETUP

Schematic layout of experimental setup of vapor compression system with all required accessories is shown in figure 2.1.

For performing the investigation on heat transfer enhancement in evaporation of R-407C three major components are required m the vapor compression refrigeration system. These are: 1. Pre-Evaporator 2. Test-Evaporator 3. After-Evaporator.

Pre-Evaporator can adjust the vapor quality of refrigerant at entry to the test-section of tube of Test-Evaporator. In Test-Evaporator, heat flux can be applied according to operating range and it has an arrangement to insert turbulent promoters in the test-section tube of heat transfer enhancement. After-evaporator can adjust the required super-heat of refrigerant at entry to compressor. In addition to the above arrangement. Hand shut-off valve can be used to vary the mass flux and evaporating pressure of refrigerant. Hence all that facilities proposed in the



1- Compressor.2- Condcnser.3- Drier 4- Sight glass 5-Oval gear flow meter 6-Thermostatic Expansion Valve 7-Pre-Evaporatow 8-Test-Evaporator 9-Aftcr-Evaporator 10-Fan 11-Accumulator 12-Shutoff valve 13-Heater rods 14-Submersible pump

Fig 2.l Experimental setup

A. Experimental Setup.

The twisted tape inserts used are made of brass strips 3 mm thickness. Twisted tapes with different twist ratio (y=H/d) of 9.067, 7.5, 6.215 are inserted in test-evaporator one by one and experimental data is acquired.

	Materials	Thickness (mm)	Pitch (H) (mm)	Width of twisted tape (d)	Twist ratio (Y=H/d)
Twisted Tape-I	Brass	3	74.58	12	6.215
Twisted Tape-II			90	12	7.5
Twisted Tape-III			108.80	12	9.067

Fig. 2.2 Specification of Twisted Tapes

III. RESULTS

From figure 3.1 and 3.2, it can be observed that for all twisted tape geometries, significant improvement in heat transfer coefficient take place, up to 35% vapor quality with increasing saturated vapor quality, it is seen that with increasing saturation pressure, heat flux and mass flux.

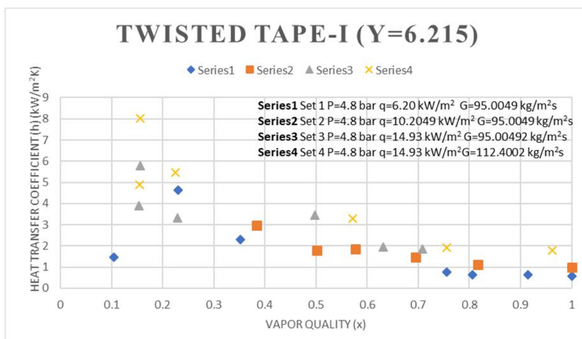


Fig. 3.1 Heat transfer coefficient with vapor quality at different operating parameters sets, using Twisted Tape- I

After 35% operating conditions, the heat transfer coefficient values remain close to each other, which indicates

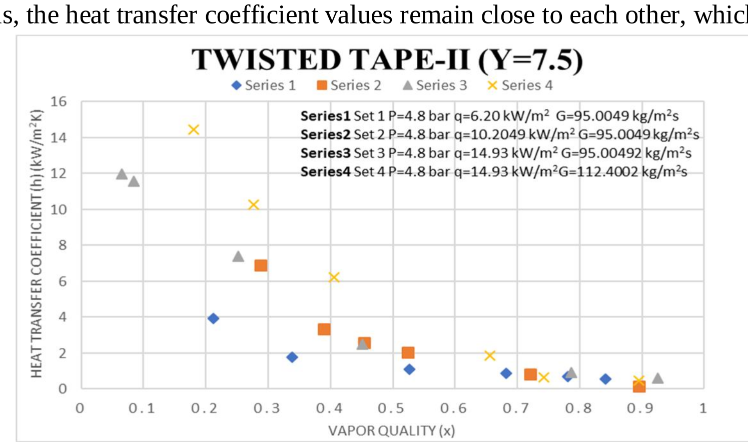


Fig. 3.2 Heat transfer coefficient with vapor quality at different operating parameters sets, using Twisted Tape-II

Insignificant improvement in heat transfer coefficient. On the other hand, in general it is found that for all two twisted tapes the improvement in heat transfer coefficient beyond vapor quality 70% is very small for all operating sets. In fact, heat transfer coefficient

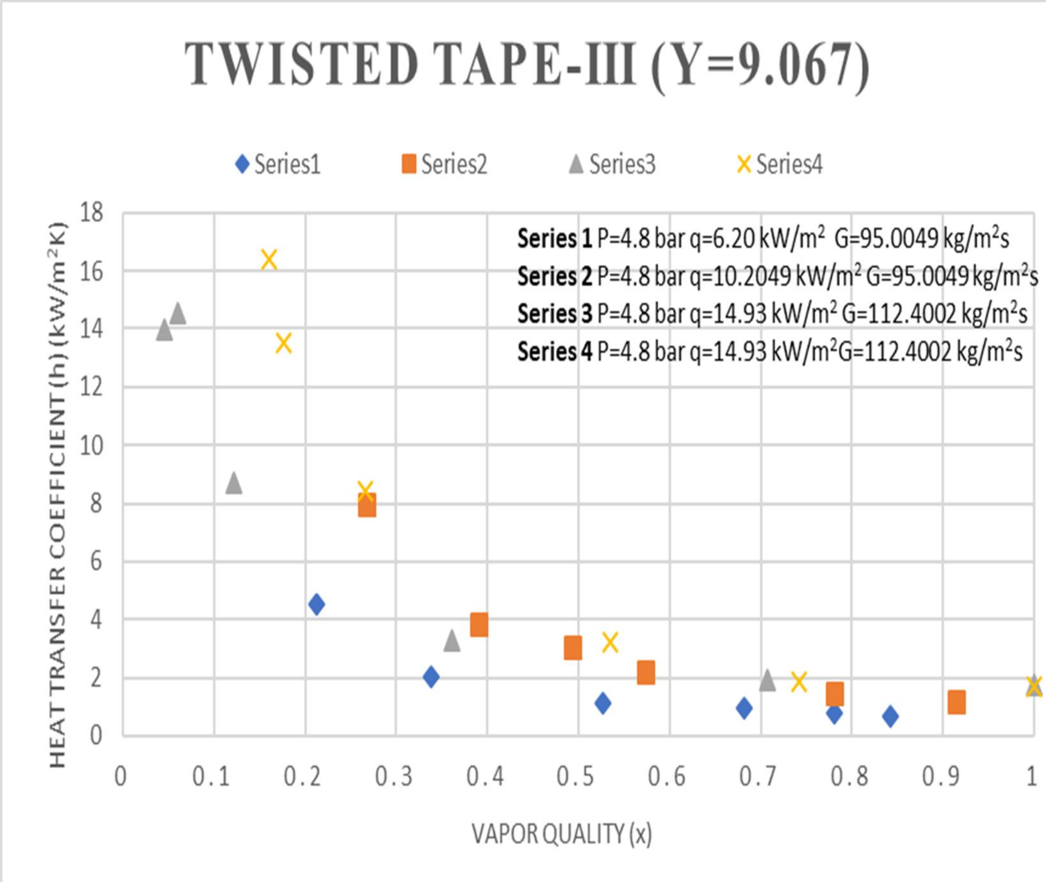


Fig. 3.3 Heat transfer coefficient with vapor quality at different operating parameters sets, using Twisted Tape-III

Values for all operating sets merge together after 75% vapor quality. Due to the presence of twisted tape inserts, the swirl produced, breaks the mass transfer resistance boundary during nucleate boiling within low vapor quality region and also helps in evaporation of low volatile components of R-407C. As a consequences rapid improvement in heat transfer coefficient can be seen up to 30% vapor quality with increasing operating conditions.

As a vapor quality increases beyond 40%, the flow accelerates with higher magnitude. The flow acceleration and induced swirl due to twisted tape support for early transitions of annular flow to mist flow between 55-70% vapor qualities. As an effect, improvement in heat transfer coefficient comes to an end after 70% vapor quality with increasing operating conditions. Hence heat transfer coefficient values for all operating conditions can be seen as merging together

From operating sets 2 & 3 for all twisted tapes, With constant conditions of pressure 4.8 bar and mass flux 95.0049 kg/m^{2}s, as heat flux increases from 10.2049 kW/m^2 to 14.93 kW/m^2, rate of nucleation increases rapidly within lower vapor quality region which holds the rate of the rise of super heat (i.e. T_{wall} -T_{sat}.) lower than rate of increasing heat flux. At the same time swirl produced due to twisted tape destroy the laminar sub layer and assist in intermixing of liquid components of R-407C. Due to all these favourable conditions heat transfer coefficient increases rapidly within lower vapor quality region with increasing heat flux.

IV. CONCLUSIONS

With all the experimentations, these are the bullet points to be added as a conclusion.

A. Twisted tapes are more effective for enhancement of heat transfer within lower vapour quality region of 10% to 60% as compared to high vapor quality range.

B. Twisted tape geometry-I, II & III gives maximum % increase in average heat transfer coefficient of 4.326%, 12.21% & 96.96% at low operating conditions of present investigation.

C. All twisted tapes inserts are showing nearly equal heat transfer performance after 70% vapour quality.

D. In general, it can be concluded that profitability of any turbulent promoters depends on its geometry and operating conditions.

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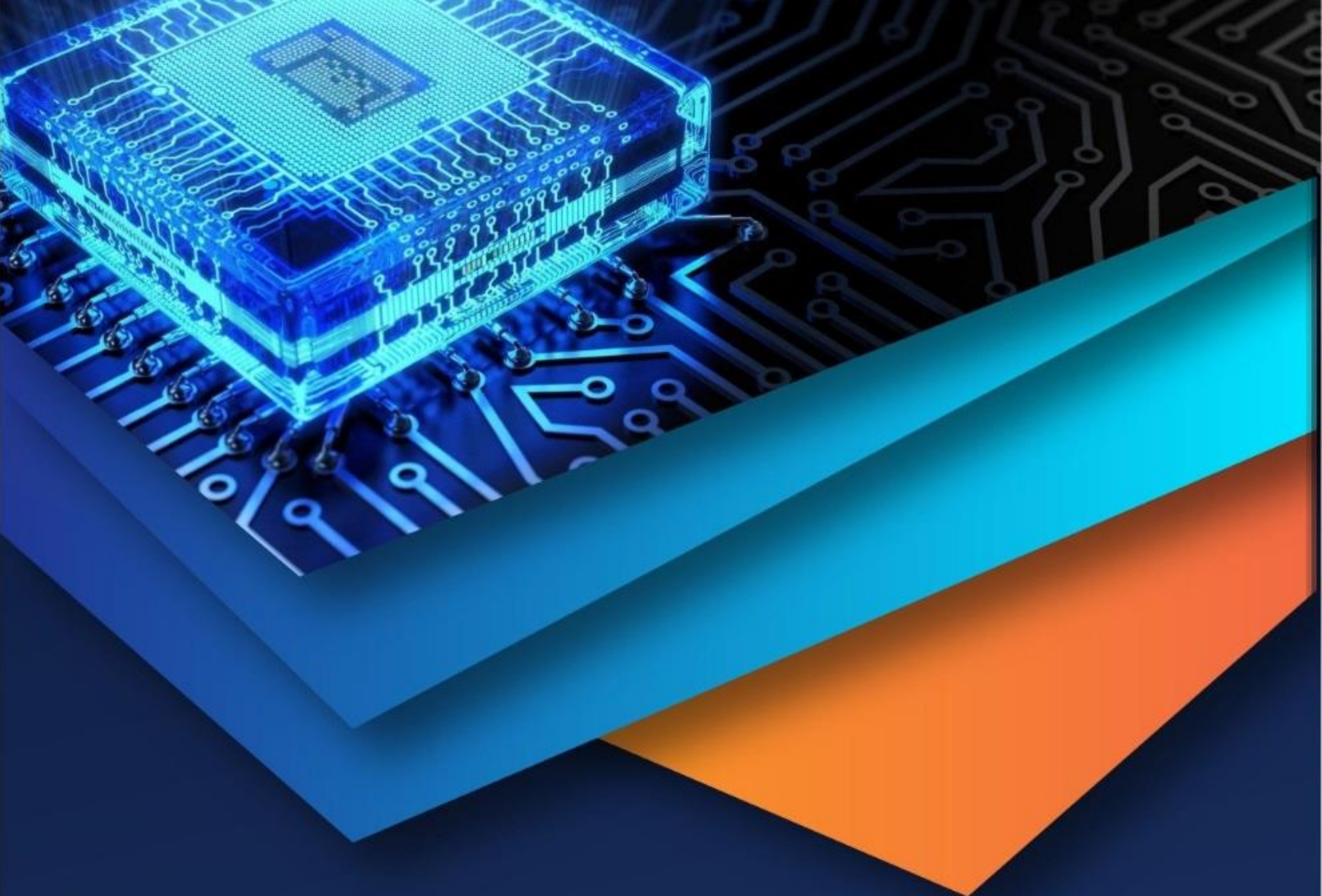

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